(12) UK Patent Application (19) GB (11) 2 359 630 (13) A

(43) Date of A Publication 29.08.2001

(21) Application No 0004506.2

(22) Date of Filing 26.02.2000

(71) Applicant(s)
Frank Thompson
37 Dale Road, MARPLE, Cheshire, SK6 6EZ, United Kingdom

Gerald Westwood
Birchfield, Church Lane, Grappenhall, WARRINGTON, WA4 3EP, United Kingdom

(72) Inventor(s)
Frank Thompson
Gerald Westwood

(74) Agent and/or Address for Service
Janvier Ltd
Birchfield, Church Lane, Grappenhall, WARRINGTON, WA4 3EP, United Kingdom

(51) INT CL[7]
G01N 22/04

(52) UK CL (Edition S)
G1N NCCR N19B2A N19C7 N19D12A N19D12F N19D12R N19F7B N19H5D5

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(58) Field of Search
UK CL (Edition R) G1N NCCR
INT CL[7] G01N 22/00 22/04 33/02
Online: World Patents Index, EPODOC, Patent Abstracts of Japan

(54) Abstract Title
Measurement of moisture content using microwave radiation

(57) The moisture content of a product may be measured in real time by directing low-powered microwaves through the product and evaluating the attenuation of the radiation and a second parameter. The second parameter may be phase (figure 1) or, in the case of a product within a measurement cavity (figure 3), resonant frequency. The apparatus of figure 1 is suitable for use with products such as dough or baked products, the arrangement of figure 3 may be used for dry ingredients such as cereals, flour, coffee, soups, granules or nuts as well as other products such as soap powders.

Figure 1:
Example: For use on-line or off-line with cooked or baked product.

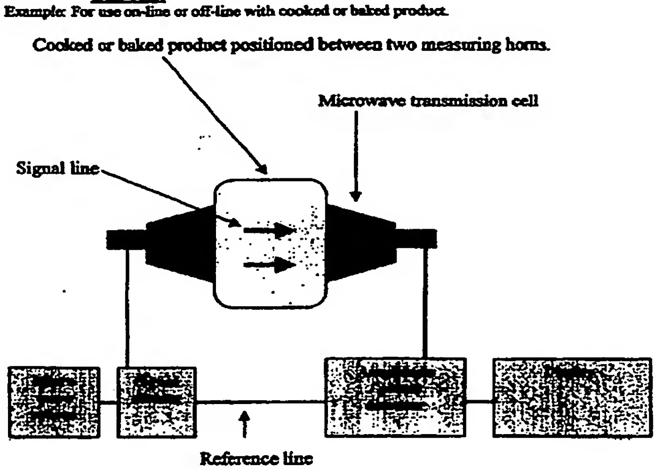
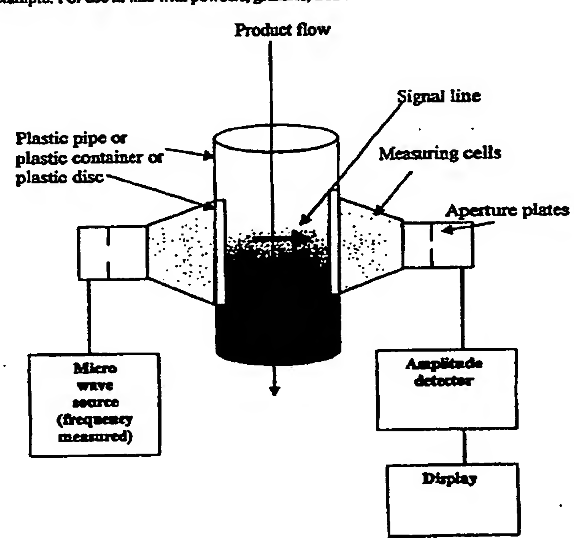


Figure 3:
Example: For use in-line with powders, granules, flour.



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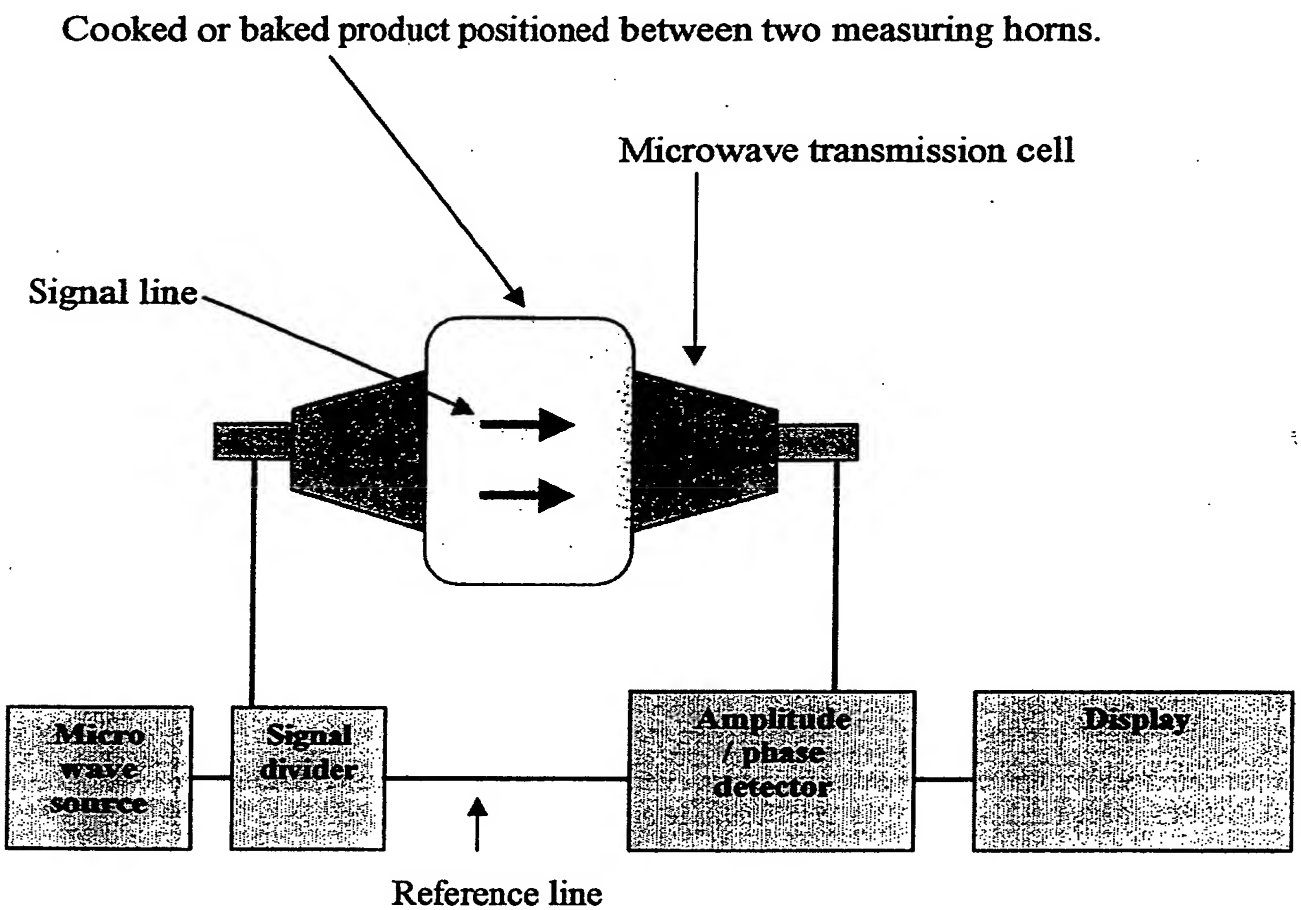
Enlarged Drawings

Drawing - Figure 1:

Example: For use on-line or off-line with cooked or baked product.



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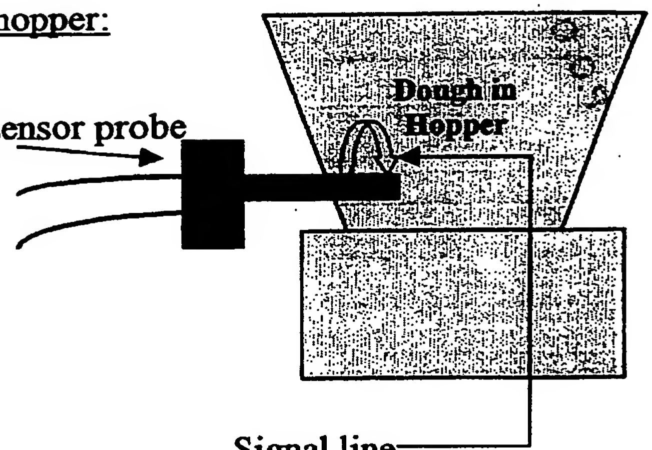
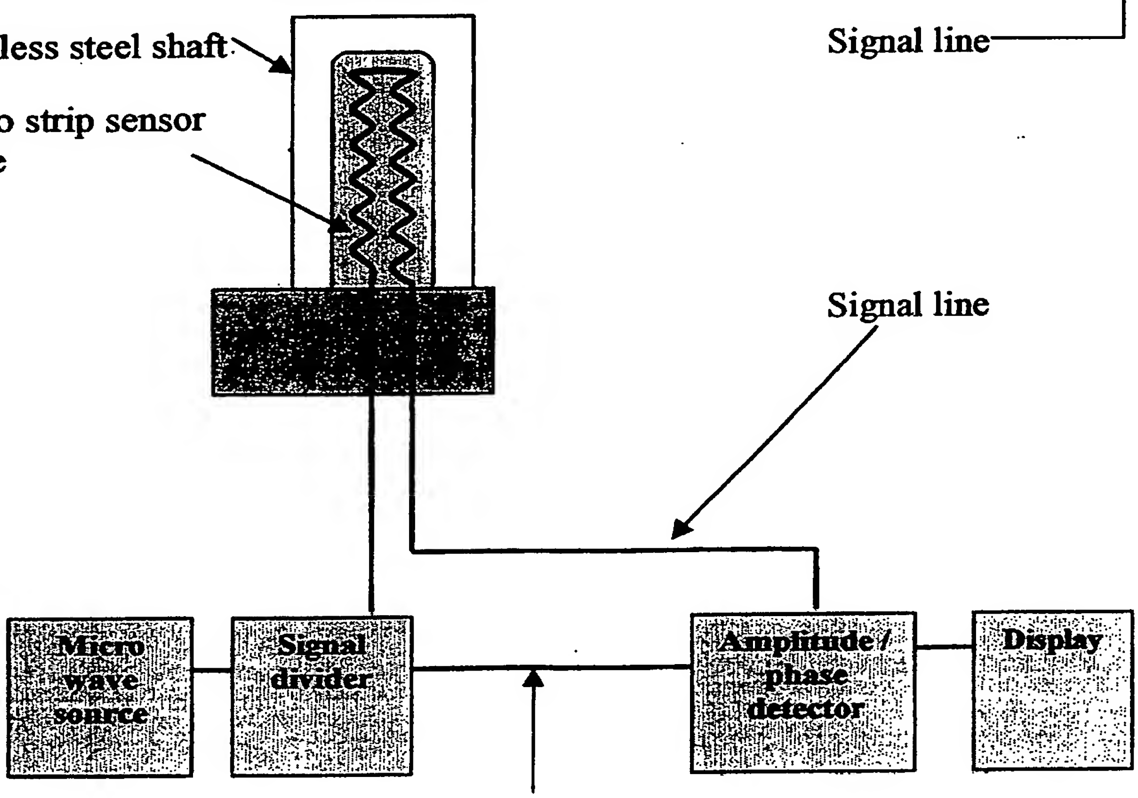
Drawing -Figure 2:
Example: For use in-line with dough mixes.

Shows microwave probe fitted into dough hopper:



Layout of probe and signal handling:



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Drawing - Figure 3:
Example: For use in-line with powders, granules, flour.

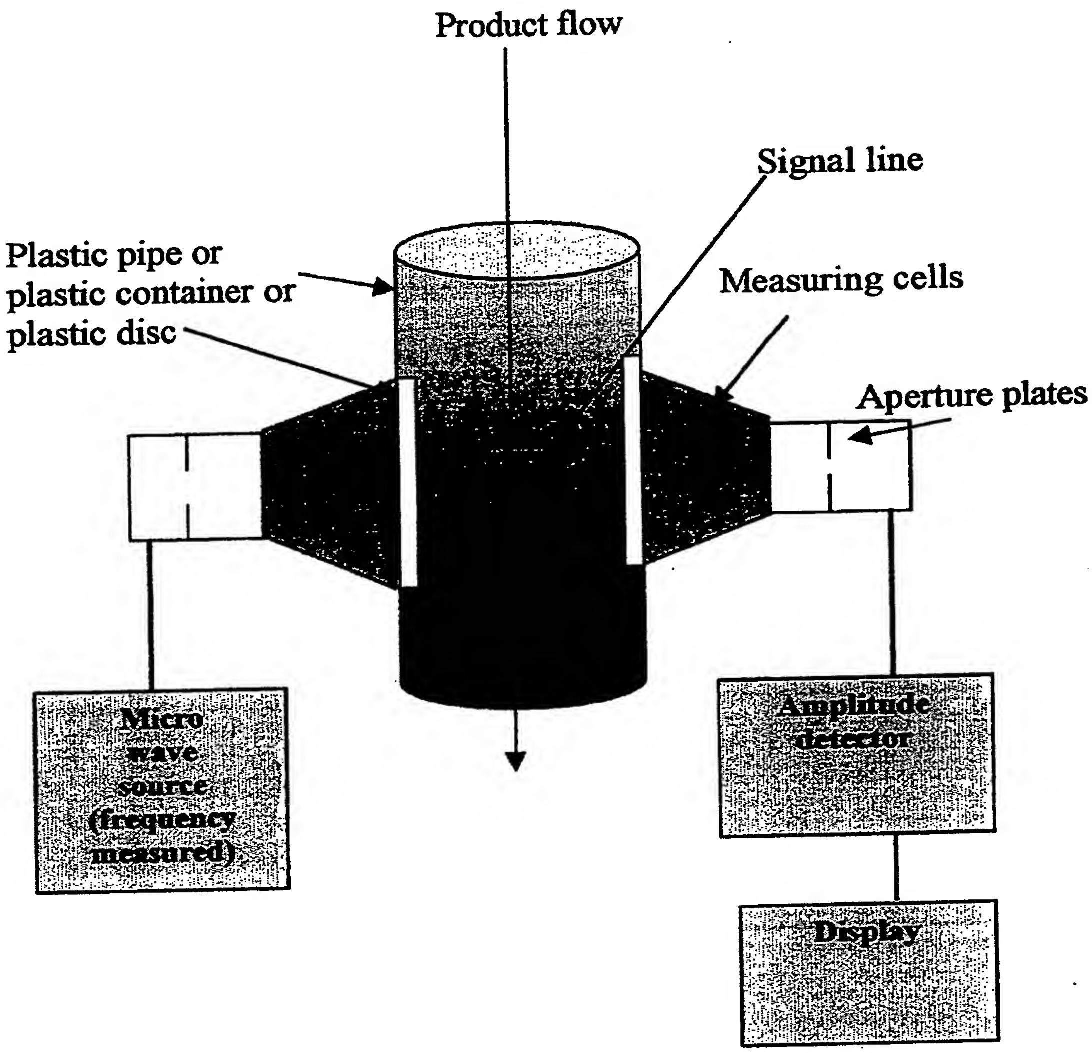

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Figure 1: Structure:

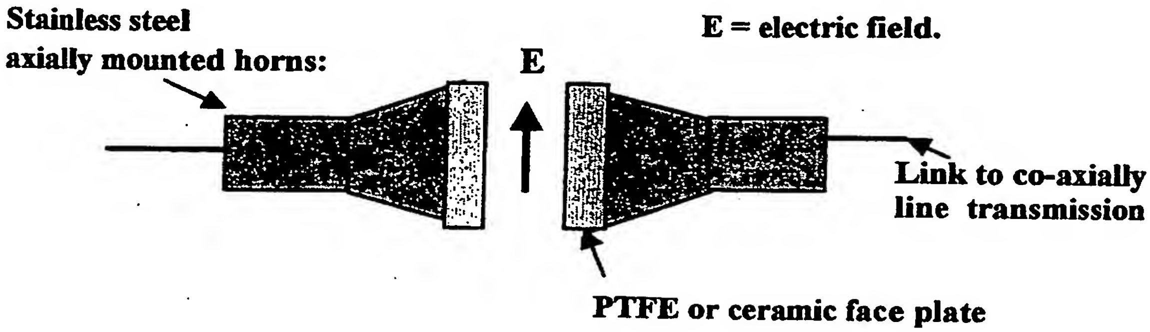
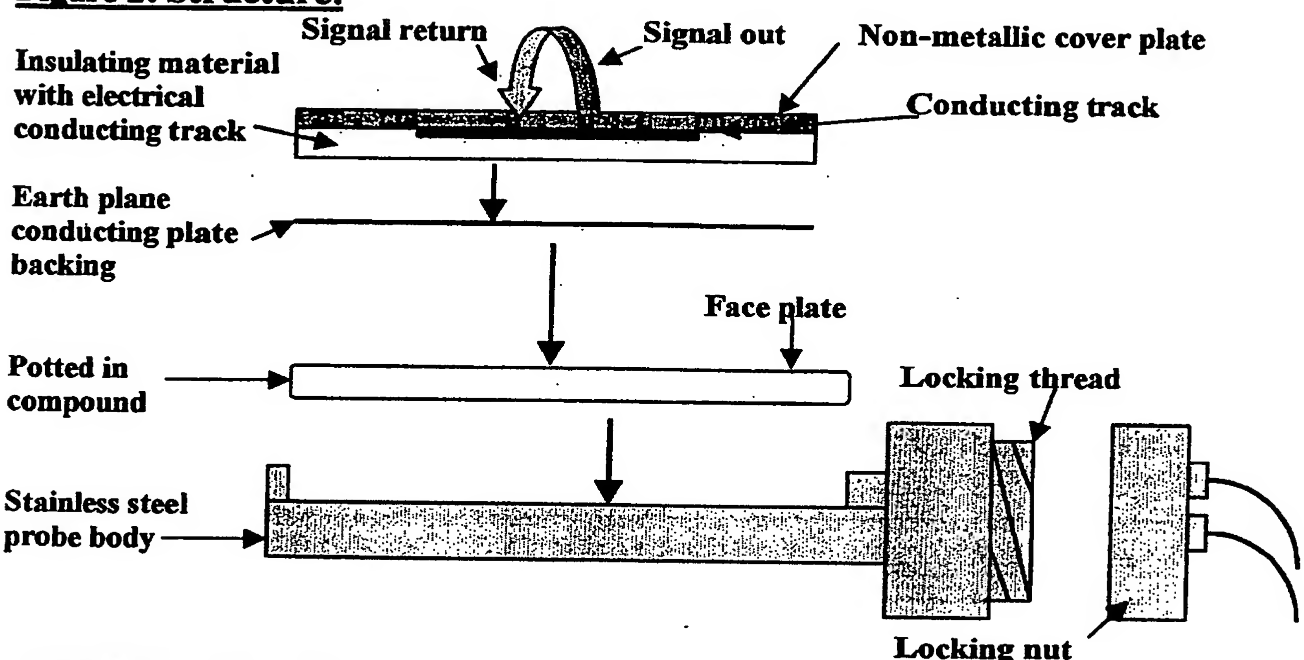
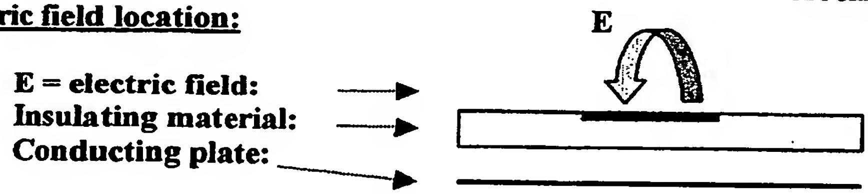


Figure 2: Structure:



Electric field location:



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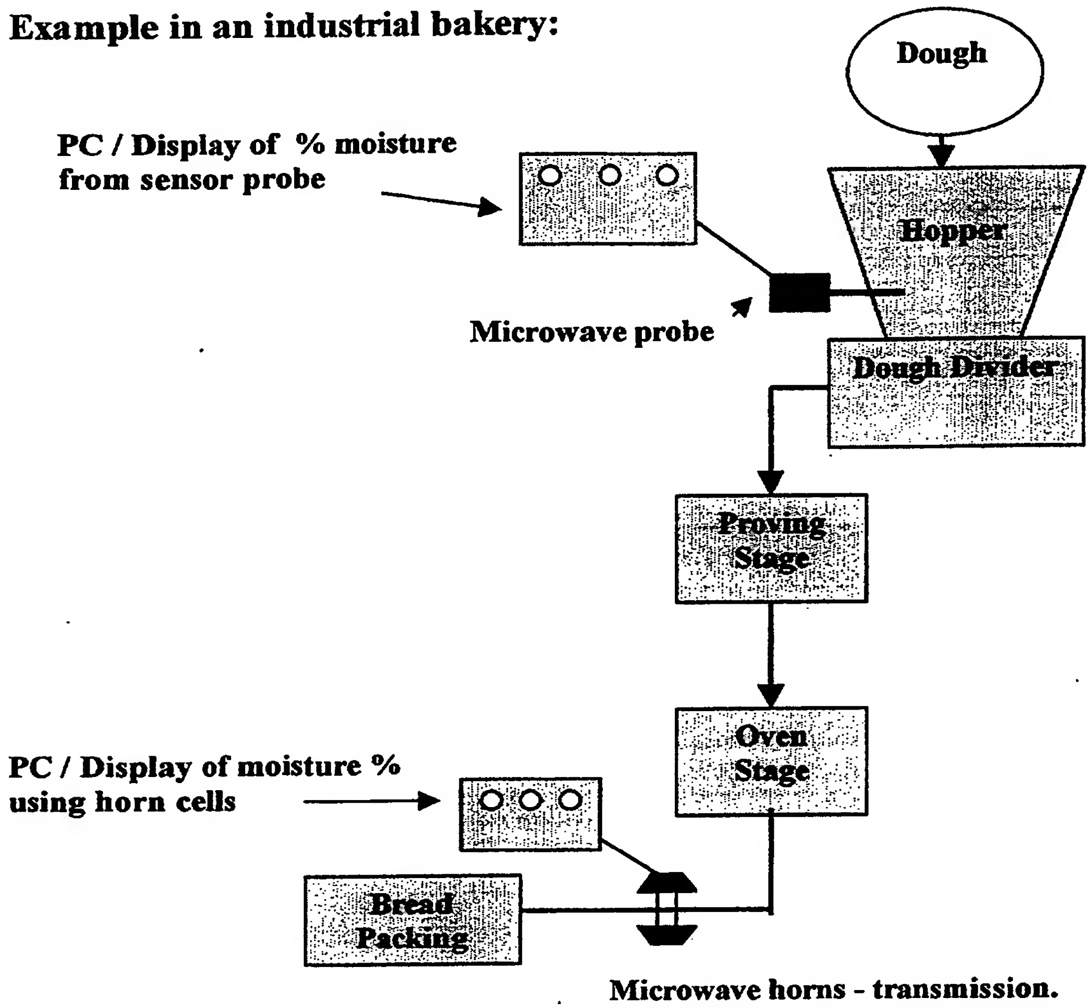
Example in an industrial bakery:



Results show that microwave method gives standard deviations comparable to oven drying method.

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Patent Office Application 1/77.

Title of invention: Moisture measurement using microwaves

The use of a customised control algorithm with a microwave system for the measurement of the sub-surface moisture content of food products (such as cereals, bakery doughs and baked products, dry ingredients, granules, soups, coffee, nuts,) and dry non-food products (such as soap powders) situated in the product flow(in-line) or immediately adjacent to the product flow (on line) is described.

Description of the essential technical features:

1) The invention involves a novel application for microwave technology to measure sub-surface moisture contents using the interaction of electromagnetic waves with water molecules in food / non-food products, in line or on-line.

2) Existing methods of moisture measurement in the food industry use:
   i) infra-red detection or standard oven drying, but are unable to measure sub-surface moisture due to the nature of the food product, or are too-time consuming, or rely on destructive sampling, or are unsuitable for an on-line/ in-line application.
   ii) microwave methods involving amplitude only measurement.

3) This invention uses changes in amplitude and phase through a unique and novel control algorithm to measure moisture contents of food and other products in-line / on-line / off -line, in real time, in a non-destructive manner, and independent of surface structure. As such this invention has major applications in food and non-food industries where real time moisture measurement is critical to quality and productivity.

4) The invention comprises a source of electromagnetic radiation, a sensor cell, and an amplitude and / or phase detection system with a unique control algorithm. The inter-relationship between amplitude and phase is used to derive a moisture value for the product under test, in a unique way,

5) The system and its components are manufactured to food manufacturing standards and the sensors are fabricated with food grade materials (stainless steel and plastic).

The preferred embodiment of the invention will be described with reference to the accompanying drawings which are shown on the next page.

The description shows three types of sensor, each for different product moisture ranges, plus a more detailed demonstration of the sensor make up and electromagnetic field direction.

An example of the invention is then described.

2.

Description

The invention uses the same microwave generation and measuring principles for all applications with different sensor arrangements for measuring differing moisture levels of products used in food / non-food manufacturing processes.

Sensor arrangements:

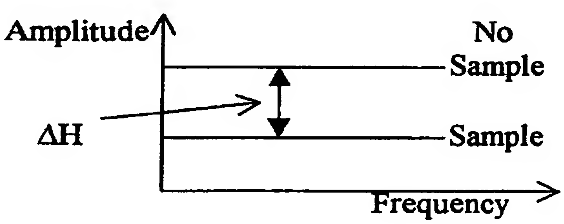
Figure 1: Transmission system for use on-line or off-line.
Example: for measuring the internal moisture of a baked loaf of bread.
Cooked or baked product positioned between two measuring horns.
Control algorithm:

$$\text{Moisture \%} = A + B \times \left\{ \frac{\Delta\varnothing}{\Delta H} \right\}$$

or

$$\text{Moisture \%} = A + B \times \left\{ \frac{\Delta\varnothing}{\Delta H} \right\} + C\{\Delta\varnothing\}.\Delta H$$

Where A,B and C are constants determined by calibration.
ΔH = change in amplitude and $\Delta\varnothing$= change in phase for values at a selected frequency or the average values from several discrete frequencies.



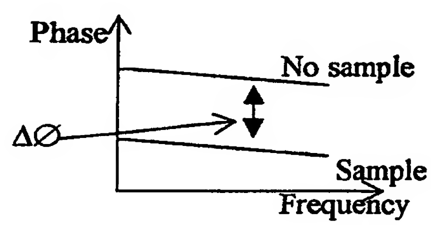


Figure 2: **Transmission**
Example: -for measuring bakery dough moisture in line.
Microwave probe fitted in line into product hopper or mixer.
Control algorithm:

$$\text{Moisture \%} = A + B \times \left\{ \frac{\Delta\varnothing}{\Delta H} \right\}$$

or

$$\text{Moisture \%} = A + B \times \left\{ \frac{\Delta\varnothing}{\Delta H} \right\} + C\{\Delta\varnothing\}.\Delta H$$

Where A,B and C are constants determined by calibration.
ΔH = change in amplitude and $\Delta\varnothing$= change in phase for values at a selected frequency or the average values from several discrete frequencies.

3.

Figure 2: **Transmission - continued:**

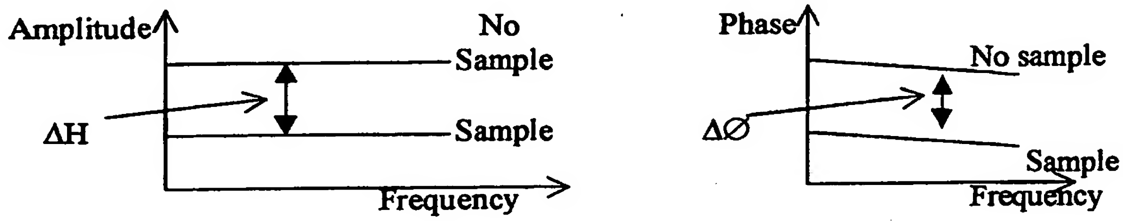


Figure 3: **Cavity resonance.**

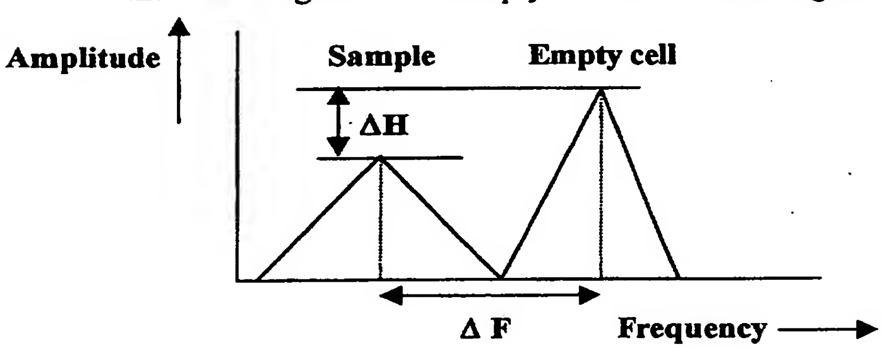
Example: -for measuring moisture of "dry" products (e.g. flour, granules, powders) in line. Probes fitted into plastic container or with a plastic disc fitted into metal pipe or container.

Control algorithm : $\text{Moisture \%} = A + B \times \left\{\frac{\Delta F}{\Delta H}\right\}$

or

$$\text{Moisture \%} = A + B \times \left\{\frac{\Delta F}{\Delta H}\right\} + C\{\Delta F\}.\Delta H$$

The appropriate algorithm is determined by the product under investigation.
A, B and C are constants that are determined by calibration.
ΔF is the change in frequency. ΔH is the amplitude change.
The change in resonance is the change in peak height and peak width between the measuring cell when empty and when containing sample.



4.

Description - Structural detail

Figure 1:
Sensor horns / cells for products with medium to high moisture contents. All materials are made of stainless steel, ceramic or plastic of food grade standard. Mounted on a stand. Horns can be rectangular or cone shaped and their shape and size depends on the shape and dimensions of the product being measured.

Figure 2:
Sensor for use with products of medium to high moisture contents, showing layers contained in probe. All materials made of stainless steel or plastic of food grade standard. Mounted in a hopper. Side view of probe. The probe size and location point depends on the nature of the product and the hopper dimensions.

Figure 3: -
Cavity sensor for use with products with low moisture contents. All materials are made of stainless steel or plastic of food grade standard. Mounted in a plastic pipe or plastic container. Can be a permanent or movable attachment. The size and dimensions of the cavity sensor depend on the product nature and dimensions.

The electromagnetic field, E, is marked for each application shown in figures 1, 2, and 3. The microwave beam is generated and divided before passing through the food / non-food product. The invention relies on the interaction of this field with the product. The differences in amplitude and phase measurements between the signal line (passing through the product) and a reference line are fed into a micro-computer to produce a moisture reading via the unique control algorithm.

Figures 1 and 2 are used in situations where products with a medium to high moisture content, give high phase shift and attenuation changes. The signal from the sensor is compared with a reference signal to produce phase and amplitude changes.
Figure 3 is used in situations where a low moisture content is to be measured.
The resonant structure is established using aperture plates and this causes the microwave beam to be reflected and re-reflected many times to produce a magnified field value.
The output signals from each of these three types of detector are fed into a microcomputer or an analogue circuit to implement the algorithm.

Example of application:

Measurement of moisture of dough in an industrial bakery.
This application utilises the sensor probe to measure moisture content of bread dough as it exits the dough-dividing stage. The dough moisture content can vary, but using the microwave moisture reading the process can be adjusted to maintain the correct moisture content. The customer is interested in the spread of the readings (standard deviation) and the method must give readings close to the reference (oven) method.

The microwave measurement is immediate, instantaneous and in real time, whilst the reference method (oven method) can take up to 16 hours to produce each reading.

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Claims:

1. The invention uses a novel way of accurately measuring moisture from changes in amplitude / phase (transmission method) or frequency / insertion loss (resonance method) changes on microwave systems.
2. The invention uses customised control algorithms to calculate the resulting moisture of the product under test.
3. The measurement of moisture using this invention can be either in-line or on-line. It can also be used off-line
4. The invention measures sub-surface (internal) moisture.
5. The invention measures moisture in real time.
6. The invention can measure moisture continuously.
7. The method of measurement in unaffected by product colour or surface conditions (wet /dry).
8. The invention can also infer the internal temperature of the product at different microwave frequencies.
9. The invention uses low powered microwaves and is safe to use in an industrial environment.
10. Moisture is presented as % wet basis or % dry basis depending on customer preference.

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INVESTOR IN PEOPLE

Application No: GB 0004506.2
Claims searched: 1-10

Examiner: Diana Pisani
Date of search: 22 August 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): G1N NCCR

Int Cl (Ed.7): G01N 22/00, 22/04, 33/02

Other: Online: World Patents Index, EPODOC, Patent Abstracts of Japan

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB1570554	BAYER AKTIENGESELLSCHAFT, see whole document.	1-7,9,10
X	EP0840108 A2	NEW HOLLAND BELGIUM N.V., see whole document.	1-7,9,10
X	WO98/29729 A1	MALCAM LTD., see whole document.	1-10
X	US5666061	JAMES INSTRUMENTS INC., see especially figure 3B.	1-7,9,10
X	US5039947	UNITED STATES SECRETARY OF AGRICULTURE, see whole document.	1-7,9,10
X	US4211970	BAYER AKTIENGESELLSCHAFT, see especially column 4, lines 20-39.	1-10
X	JP080015845 A	SNOW BRAND MILK PROD. CO. LTD., see WPI abstract accession no. 1996-256115 and first page figure.	1-7,9,10

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